Book Reviews

Simulation and Identification of Organized Structures in Flows

Edited by J. N. Sorensen, E. J. Hopfinger, and N. Aubry, Kluwer, Dordrecht, The Netherlands, 1999, 508 pp., $237.00

This volume contains 44 papers presented at a conference held in Denmark in 1997. The papers are organized into 10 chapters. The papers are mostly on numerical simulation of transitional or very low-Reynolds-number turbulent flows, with a few on related experimental measurement techniques. Several papers have appeared elsewhere in other forms. The papers are mostly short and, as conference papers, of high quality.

Over the past three decades, the simulation of flows as a technology has matured to some extent. So it is about time to focus deeper on structure identification, which has considerable practical value. I think this volume has a good collection of papers on structure identification and this is where its value lies.

The presence of the word "and" in any title usually signals to me a lack of focus. The simulation papers in the volume, in general, are not that new and do not have a central presence. Instead, I wish the volume had concentrated on structure identification, with those papers organized into chapters devoted to its various aspects. This would have firmly highlighted a value of the technology of direct numerical simulation that has not been recognized very widely. A volume organized in that manner would have served the reader eminently well.

The subject of structure identification has a long way to go, though, and the papers in the volume are indicative of that. There is an overwhelming effort toward finding universal and perfect definitions of flow features and techniques for identification. It is not yet recognized that this is perhaps a chimera and that, instead, application-specific definitions and approaches would lead to more useful progress. A volume focusing on these practical aspects of the technology would be valuable.

This volume is suitable for advanced numerical research scientists, who should be able to sort the papers according to their needs.

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Discretization Methods in Structural Mechanics

Edited by H. A. Mang and F. G. Rammerstorfer, Kluwer, Dordrecht, The Netherlands, 1999, 371 pp., $186.00

The book under review presents the proceedings of the International Union of Theoretical and Applied Mechanics (IUTAM) Symposium on Discretization Methods in Structural Mechanics held in Vienna, 2–6 June 1997, and has 42 papers. These papers are divided into eight thematic sections: 1) discretization strategies, adaptive methods; 2) large displacements and rotations; 3) dynamics; 4) novel alternative numerical methods; 5) sensitivity analysis and optimization; 6) contact problems and finite element/boundary element coupling (FE/BE); 7) micromechanics and composites; and 8) plasticity and damage. The symposium was attended, in addition to "several Austrian graduate students and research associates," by "71 persons from 23 countries," However, most of the 42 papers presented at the symposium are of European origin. The book thus presents a very good bird's eye view of ongoing European research in computational structural mechanics.

The section Discretization Strategies, Adaptive Methods has six papers. The paper by Zienkiewicz, Boroomand, and Zhu reviews the patch-recovery-based error estimator proposed and developed by the authors in 1992. The error estimators are used to develop an adaptive mesh for solving Poisson-type problems using triangular and quadrilateral elements. Stein and Ohnimus present an integrated adaptive approach that updates both the finite element mesh and the physical model for plates and shells in the vicinity of such discontinuities as thickness jumps, physical supports, and point loads. Three-dimensional models are used near these discontinuities. For adaptivity, an error estimator, termed the posterior equilibrium method (PEM), is employed. Bischoff and Ramm present a paper on three-dimensional shell formulation. The concepts of assumed natural strain and enhanced assumed strain shell finite elements for large deformation are developed and employed to analyze a hyperelastic cylindrical shell. To avoid "thickness locking," a modification to the thickness strain is presented. Scherf and Wriggers, using an error estimator suggested by Rheinboldt, present an adaptive method to study the frictional contact problem of rubber sealing in which an elastic block is pressed by two very stiff jaws. The results from an adaptive mesh are in good agreement with the reference solution. The paper by Cirak and Ramm examines the nonlinear response of shells by using adaptive methods. The paper discusses the error estimators for nonlinear problems that have singular points (e.g., at the buckling load) and problems that have plasticity. The example considered is that of an open cylinder subjected to two distributed loads in opposite directions at the free edge. The last paper in this section, by Beer, evaluates the existing discretiztion methods (both finite and boundary element methods) for problems in geomechanics (underground excavations and faults).

The second section, Large Displacements and Rotations, is rather short, containing only three papers. The first paper deals with traversing limit points in nonlinear structural analysis (Schweizerhof, Rottner, Alefend, and Lenhardt) using, as opposed to direct solvers, iterative schemes (preconditioned conjugate gradient and Lanczos-type solvers) to solve the linearized equations. The use of parallelization in iterative solvers is also discussed. The paper by Gaspar and Domokos studies the computation of global equilibrium paths for beam structures that can be used either as an iterative-free continuation scheme or as a global algorithm that can identify all equilibria in the given parameter domain. Finally, Onate and Zarate present a nine-degree-of-freedom (DOF) thin triangular plate/shell element with only translational DOF and used for studying nonlinear shell structures under transient loads.

The third section, Dynamics, constitutes a significant part of the book and includes seven papers. A very brief paper by Prof. Crisfield and coworkers deals with three aspects of the nonlinear finite element method (FEM): objectivity of strain measures as applied to three-dimensional beam problems, energy and momentum conservation in transient response calculations, and physical and numerical damping. Wunderlich and Rapolder present a study on the dynamic soil–structure–fluid interaction problem of unanchored liquid storage tanks. The computations are performed with a cluster of computers using the parallel virtual machine (PVM) language. The authors are able to achieve a speedup of seven for a 10-workstation cluster. Rotational symmetry is used to reduce the computational effort. Choi and Chung study error control in dynamic problems. The authors employ both adaptive mesh refinement and time-step control using a quadratic function approximation (an extension of the Zienkiewicz–Zhu method to dynamic problems) for stresses and accelerations. Results are presented for an elastic bar subjected to a step loading.

In recent years, a number of studies have appeared in which displacement and velocities are considered independent of each other in studying transient problems. Most of these studies have been restricted to applications in fluid mechanics. In one of the most interesting papers of the symposium, Wiberg and Li employ such an approach in solving nonlinear structural dynamics problems. The authors present a discontinuous Galerkin method by approximating the displacements and velocities using piecewise bilinear functions in space-time. These functions may be discontinuous at discrete time levels. The method is applied to study the dynamic elastoplastic response of a beam and impact of a finite bar whose stress strain response is represented by using a bilinear relationship.

The next two papers are on the seismic response of a damaged concrete gravity dam (Valliapan and Yazdhi) modeled using a continuum damage approach and the static and dynamic nonlinear response of thin shells using an elastoplastic constitutive relation (Damjanic). The paper on thin shells employs, for transient calculations, a form of midpoint rule that conserves total linear and angular momenta for autonomous motion and conserves total linear and angular momenta and energy for the Hamilton case. The last paper in the section, written by Poth et al., will be of considerable interest to the readers of this journal because it pertains to the motion of tethered satellite systems. The authors present a formulation that expresses the motion of the tether not in terms of the usual Cartesian coordinates but by an alternative method that employs the elongation and the orientation of the tangent vector, termed the η–$\boldsymbol{t}$ representation. Such a representation allows the motion to be represented as a fast motion and a slow motion, and the two can be separated from each other, leading to computational efficiencies. The tether is modeled as a string without bending and torsional stiffnesses, and the satellites are modeled as rigid bodies.

The section Novel Alternative Numerical Methods deals with newer approaches in performing computational structural analysis and contains seven papers. These papers deal with such topics as the boundary element method (BEM), the meshless FEM, and neural networks. The three papers on the BEM investigate such topics as the development of a field boundary element formulation for axisymmetric finite strain elastoplasity (Kuhn and Kohler); computation of derivatives of the structural response, such as displacements, up to the boundary in the BEM (Wendland, Schulz, and Schwab); and a hybrid-Trefftz finite element formulation (Kompis and Bury). The two papers on meshless methods deal with a new meshless finite element approach (Yagawa, Yamada, and Furukawa) termed the free mesh method and a multigrid approach for solving boundary value problems in an adaptive manner using finite difference methods that are generalized for arbitrary irregular grids (Orkisz, Lezanski, and Przybylski). The free mesh method of Yagawa et al. is designed for parallel computers. The global stiffness matrix is assembled node by node independently, and the method is demonstrated for a heat conduction problem having 10^6 DOF running on a MIMD-type parallel computer. Waszczyszyn, Pabisk, and Mucha present a hybrid approach that combines numerical methods such as finite difference and finite element with neural networks for solving elastic–plastic problems. No significant reduction in the CPU time was shown by the hybrid approach. The second paper on neural networks, by Stavroulakis and Antes, deals with their use in an inverse problem such as detecting cracks in an elastic body.

The next two sections in the proceedings are quite short. Together, the two sections, Sensitivity Analysis and Optimization and Contact Problems and FE/BE Coupling, consist of five chapters. Professor Ahmed Noor and J. M. Peters review their considerable work on sensitivity analysis using the reduced-basis method. The authors also discuss the use of such tools as ADIFOR for analytically determining the sensitivity of complex structures such as that of sandwich panels and viscoplastic solids. In a very interesting application of the sensitivity approach, Banichuk and Saurin determine the J-integral in cracked panels. The two papers on FE/BE coupling are on the interaction between vibrating structures and an acoustic field (Chen, Hofstetter, and Mang) and on soil–structure interaction (Pavlatos and Beskos). The paper on contact studies (Payer, Meschke, and Mang) deals with the contact of a tire with snow. The tire (rubber) is modeled using incompressible materials (modeled with a three-dimensional hybrid element obtained from the 3-field Hu–Washizu variational principle), and the snow is considered to behave as a viscoplastic material. In addition, the study accounts for large deformations, frictional contact (using a regularized Coulomb friction law), and reinforcing cord layers. Out-of-core iterative methods are used to solve the large number of equations (142,569 in one case).

One of the most fascinating applications of computational methods is in analyzing structures made of composite materials. The analysis is complicated by the fact that there is a significant interaction between the physical phenomena occurring at various spatial scales (micro, macro, and meso). The section Micromechanics and Composites consists of seven papers and deals with computational issues in composites. Fish, Shephard, and Beall have developed an automatic crack propagation analysis that can be used for heterogeneous materials. While using homogenized material properties away from the crack tip, the analysis uses an explicit representation of the material microstructure at the crack-tip vicinity. The analysis allows one to understand how the presence of fibers influences crack growth in inhomogeneous materials. The paper by Bohm et al. deals with understanding the thermomechanical response of structures made from inhomogeneous composites. Material models capable of representing the material behavior at both meso and macro scales are used. This the authors accomplish by employing the Mori–Tanaka model of including thermoelastic inclusions in a thermoelastoplastic matrix. Schrefler et al. investigate the response of periodic composites by obtaining nonlinear constitutive relations (caused by elastoplastic behavior of components and the possible slip between the matrix and the fibers) for an equivalent homogenized material. Reisner and Fischer investigate improving the balance between strength and ductility by using the martensitic transformation (solid-solid phase transition) for such materials as zirconia-reinforced ceramics, shape memory alloys, and steels having transformation induced plasticity (TRIP). The next three papers study the global behavior of composite structures. Wagner and Gruttman study the response of laminated shells. Adam, Irchik, and Ziegler investigate the dynamics of composite beams in the presence of inelastic slip that may develop between the physical interfaces, and Rinderknecht and Kroplin investigate delamination growth in composites using two different approaches: a damage mechanics approach and a linear elastic fracture mechanics approach. The authors employ a two-dimensional macroscale model and point out that even three-dimensional macroscale modeling may not predict accurate delamination growth if appropriate micromechanical mechanisms are not included in such an analysis.

The last section, Plasticity and Damage, has seven papers dealing with such topics as cyclic plasticity, enhanced low-order elements, FE modeling of localized failure for quasi-brittle materials such as concrete, metal forming, and inelastic crack damage. Also studied are the thermoplastic analysis of shells (Miehe and Schley) and the integrated physical–mechanical modeling of structures used in nuclear power plants subjected to thermal loads and radiation (Ugodchikov and Ugodchikov). Babuska and Li study the plastic response of one-dimensional structures and point out that the constitutive laws are full of uncertainties. Further, these uncertainties are much larger than the computational errors and require probabilistic description of the constitutive laws. Borst, Groen, and Heeres develop enhanced low-order elements, for soils and rocks, that will not suffer from locking for the angle of dilatancy being zero, negative, or positive. The angle of dilatancy determines the plastic volume change. Samuelsson, Mattiasson, and Wendt investigate the finite strain elastoplasticity in the sheet metal forming processes. For enhanced numerical stability in time integration, "exaggerated inertia terms" are considered in conjunction with an explicit method. The proposed algorithm works well for a displacement-controlled forming process compared to a load-controlled one. Kratzig and Konke present a multilevel simulation (structural, finite element, element Gauss point, and material point level) strategy to study the elastic–plastic response of structures in the presence of cracks. The authors suggest that a combined approach that uses both the continuum damage models and the fracture mechanics approach be taken to study complete damage evolution.

Finally, Professor Stein in his very valuable concluding remarks summarizes the research presented at the symposium and points out the need for more research in such areas as error-controlled adaptivity, especially for nonlinear problems; stochastic analysis; inverse problems; and reliable integration schemes for transient problems.

In conclusion, the book under review presents a very good overview of the research (up to 1997) in computational structural mechanics. The papers are brief, but the references can provide all of the details that a reader needs. The overall quality of printing is good. Clearly, Professors Mang and Rammerstorfer have spent a considerable effort in putting together the proceedings. They deserve our thanks. Two disappointments about the book: the high price (only big libraries can afford it) and the meager participation of the U.S. computational structural mechanics community. Imagine, out of 42 papers presented in a major international symposium, only three are from the United States!

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